November 2017
Publication no. cmr 17-013-TB2

Dowel Bar Retrofit

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TECH BRIEF

MoDOT

This document is a brief technical summary of the MoDOT case study ***Dowel Bar Retrofit Case Study for Washington and Other Leading States*** *which is included in a larger report,* ***Concrete Repair Best Practices: A Series of Case Studies****, Publication no. cmr 17-013, November 2017.*

Introduction

This Tech Brief summarizes a “case study” report for dowel bar retrofit (or DBR) for the lead State of Washington. This report brings in the specifications and experience of other State leaders and contractors from Missouri, California, Minnesota, and Utah. DBR technology has been improving over many years to provide increased load transfer efficiency (LTE), typically increasing from 30 to >80 percent for existing transverse joints with no dowel bars but also for working transverse cracks which prevents future joint and crack faulting and roughness after grinding.

Washington constructed its first full-scale DBR project in 1993 for the repair of a severely faulted concrete pavement. After solving some initial problems, many DBR projects were constructed with long-term service life extensions up to 22 years for jointed plain concrete pavement (JPCP). The other States achieved similar results. Interviews with State and contractor staff indicate there are several key activities that must be done to provide effective DBR.

Pre-Construction DBR Considerations

Washington and the other States typically perform DBR to provide JPCP and jointed reinforced concrete pavements (JRCP) improved LTE of non-doweled transverse joints and working cracks that result in long-term (10 to 20+ years) prevention of joint or crack faulting after diamond grinding. Of course, there are projects where this much life extension is not possible due to severe durability or cracking problems.

Appropriate Existing Condition for DBR. In Washington, ideal candidate projects for DBR are those that are 25 to 35 years old and have mean fault measurements between 0.125 and 0.25 inches. Projects with mean faulting greater than 0.5 inch are diamond ground only, without DBR. JPCP with excessive amounts of joint faulting would also typically have large amounts of loss of support and rocking panels, which DBR may not overcome.

Some slots in Washington have failed when longitudinal cracks in the existing pavement form at a DBR slot. When a DBR slot is intersected by a longitudinal crack, Washington does not chip out the slot and place a DBR, but will rather just clean and reseal the sawcut with an epoxy material. Sound concrete must exist at transverse joints and cracks throughout the depth of the slab. Coring and visual inspection is required to ensure there exists sound portland cement concrete (PCC) in the lower portion of the slab. If there is significant lower slab deterioration (lower portion of core falls apart), Minnesota strongly recommends that DBR may not be effective and full depth repair is more effective for that joint.

Are Dowel Bars Required to Control Joint/Crack Faulting? This is the main question that must be answered to justify spending additional funds for a concrete pavement restoration (CPR) project. A quick answer can be obtained by examining the existing pavement faulting that has accrued since construction or a previous diamond grinding operation. The typical magnitude of what is considered "significant" faulting for a JPCP with short joint spacing is 0.125 inch, which affects the International Roughness Index (IRI) and user ratings significantly. If an existing JPCP has faulting of this magnitude or more, it is highly likely that after diamond grinding the existing pavement will begin to fault again at a more rapid rate.

The AASHTOWare Pavement ME Design software can be used to determine the increased life for specifying CPR/DBR for a project. The "Restoration" pavement type must be chosen, and the required data must be entered to run the program to estimate mean joint faulting over the next 10 to 20 years. Figure 1 shows the projected joint faulting for a JPCP over a future 20 years, both with and without DBR of varying diameters.

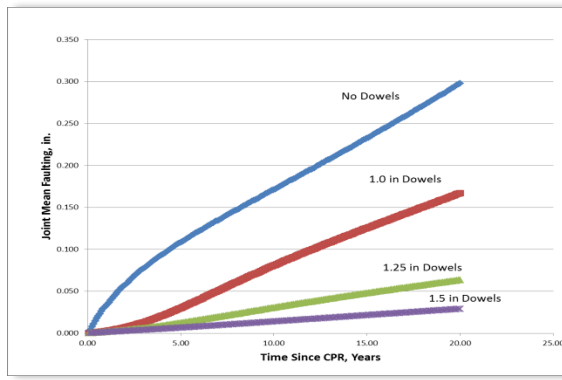

Figure 1. AASHTOWare Pavement ME Design example output for a JPCP CPR grinding project, both with and without DBR.

Design and Layout of DBR. Washington has devoted substantial effort to the development of a detailed joint DBR layout plan and details, as shown in the Washington State Standard Plan for DBR, A-60.20-03 (see the DBR case study report for full citation). "Dowel Bar Retrofit: Do's and Don'ts," by Pierce, Weston, and Uhlmeyer (2009), is highly recommended for many more details and step-by-step DBR.

Washington requires three dowels per wheel path spaced at 12 inches. One key dimension of note is the 18-inch spacing from the outer edge of the slab (paint stripe) to the first dowel bar to prevent corner cracking. Another notable dimension is the large 1.5-inch dowel diameter, which is extremely effective in reducing concrete/steel bearing stress and joint

or crack faulting. Dowels are epoxy-coated, and expansion caps are tight-fitting, non-metallic material. Chairs are epoxy-coated or non-metallic material.

Washington, Utah, and California (>9-inch slab) use the 1.5-inch dowel diameter in their DBR. Missouri (<10-inch slab) uses 1.25 inches, and Minnesota and California (<9-inch slab) use 1.25-inch dowels. The different sizes appear to work for the States involved with the projects they have constructed. For only three dowels per wheel path, the use of a 1.5-inch dowel may very well be worth the extra cost given the variations in placement of DBR. Projects in California and Minnesota have shown an increase in transverse joint LTE from 30 or less to over 80 percent after DBE, which indicates why very little faulting has developed.

Dowel Bar Retrofit Specifications

Washington and the other States appear to have effective specifications and special provisions for DBR. Contractors who have worked in these States affirm they are reasonable and effective. Table 1 summarizes the specifications, special provisions, and other documents from the States.

Table 1. Summary of State specifications for DBR.

State	Specification/Documents
Washington	WSDOT 5-01 Cement Concrete Pavement Rehab. Standard Plan A-60.10-03 “Dowel Bar Retrofit: Do’s and Don’ts”
Minnesota	MnDOT 2302 SP. Concrete Pavement Rehab Best Practices Manual, MN Local Road Research Board
California	**Section 40-1, SSP 41-.02, RSP P10** Dowel Bar Retrofit, Revised Standard Plan P7 **SSP 41-8. DBR** **SSP 41-8.03L** **SSP 41-8.01D(6)**
Missouri	**MoDOT** Standard Specification 613.40 MoDOT Standard Drawing 613 (Sheet #4)
Utah	UDOT Standard 2754

Removal of PCC in DBR Area and Cleaning the Area. All of the States in this study used diamond saw blades to cut the dowel slots. Slots are not cut near cracks, as this leads to more cracks and spalling. Light jackhammers (< 30 lb) are used to remove material to minimize breaking through the slot. Slot surfaces are cleaned by sandblasting to remove slurry caused by saw cutting, which is critical for bonding. Contractors emphasize that sandblasting is essential to get the slurry out of the slot. Caulking filler is neatly placed in the joint across the slot bottom and sides and not any wider, since that reduces the effective bonding area.

Lightly Coated Dowel. All of the States believe that it is essential that the dowel be lightly coated with lubricant or parting compound prior to the dowel assembly being placed into the slot. If not lubricated, ensuing attempts by the joint or crack to open and close will result in cracking through the slot material and farther into the slab.

Dowel Bar Assembly. The lubricated dowel bar assembly is placed into the slot, as shown in Figure 2. The dowel is lightly coated with a parting compound, foam core board is placed on the dowel to establish the existing concrete joint, and end caps/chairs are placed on the ends of the dowels that will provide a minimum of ½-inch clearance from the bottom of the slot. The assembly is placed in the center of the slot. Other States use a similar approach.

Figure 2. Inserting dowel bar assembly into slot (Photo courtesy of Jeff Uhlmeyer, Washington State DOT).

Joint Separation Material and Sawing of Joint. The foam insert in Washington is a ⅜-inch-thick material that is placed at the dowel center to maintain the transverse joint. The foam insert used to keep incompressibles out of transverse joints is called "foam core board." The foam insert must be capable of remaining in a vertical position and tight to all edges during the placement of the concrete patching material. Caulking filler used for sealing the transverse joint at the bottom and sides of the slot is a silicone caulk. The foam insert must fit tightly around the dowel and to the bottom and edges of the slot and extend to the top of the existing pavement surface. The insert must go all the way to the bottom of the slot to prevent material from flowing from one side to another. The slot is overfilled a little to provide for diamond grinding of the pavement surface. A Utah contractor stated that maintaining the proper location, especially standing it up vertically, is perhaps the most important installation item.

DBR Slot Material. Washington uses prepackaged mortar extended with aggregate (example product: CTS non-shrink rapid set grout). See WSDOT Standard Specification Section 9-20 for strength, scaling resistance, and freeze-thaw requirements. This material has provided good performance in Washington. The slot material is placed, consolidated, and cured until ready to open to traffic. Saw cut slots are prepared such that dowel bars can be placed at the mid depth of the concrete slab, centered over the transverse joint, and parallel to the roadway centerline and surface.

California uses polyester concrete consisting of polyester resin binder and dry aggregate. The existing slot surface is treated with high molecular weight methacrylate bond agent. Minnesota uses packaged, dry, non-shrink, rapid hardening concrete conforming to ASTM C 928 (R3) plus other tests. Missouri uses rapid set concrete patching material. Utah uses prepacked, dry, non-shrink, rapid hardening concrete.

Inspection/Acceptance

Washington has a detailed inspection plan in their construction manual that includes meeting with the contractor, visual confirmation of slots, sandblasting faces clean, aligning dowels properly, ensuring foam core inserts are vertical to form the joint, consolidating fill material, and working equipment to accomplish these tasks. (see DBR Case Study for Washington and Other States, 2017). Contractors in Washington believe that inspection of the slot is extremely important. Sandblasting is believed to be the only way to get it clean (water blasting does not appear to work as well) and aids bonding. Another critical aspect is the foam core board inspection. If the board "rolls over" it is easy to get buried in the fill material and ultimately will result in spalling, so it is vital to keep the foam core board straight up to form the joint.

California uses core tests to determine alignment, placement, and polyester concrete consolidation. California requires a test section at least 1 traffic lane wide and 300 feet long.

The contractor must drill cores for the Department's evaluation of dowel bar placement and polyester concrete consolidation. Dowel bar retrofit is accepted based on the core tests.

Minnesota requires that, prior to major DBR operations, a DBR construction demonstration is performed that includes installation of 24 dowels. The engineer marks three locations for 6-inch coring at center of dowel. The engineer will examine the core to see if dowel anchoring is acceptable. If dowels are located improperly or air voids exist around the dowel, replacement is required. A 30-day warranty on all repairs is specified that starts after diamond grinding is completed in a lane.

Utah requires a similar 24-DBR test section. Cores are taken for verification of alignment, placement, and consolidation. Slot material approval is required.

Missouri inspection includes visual examination of the slots, sandblasting the faces, placement of the dowel assembly, foam core inserts, and equipment. Tests are specified for the slot material. Unacceptable DBR repairs must be mitigated by a method proposed by the contractor and acceptable to the engineer. Missouri contractors agree that a preliminary test section (of a few DBR installations) is a good idea to ensure the contractor knows how to properly do DBR work.

Performance of Dowel Bar Retrofit

Washington. Overall, DBR performance has been good with very few performance issues. If constructed as part of CPR and done earlier in the JPCP life, the future pavement life can be extended 20 to 30 years. An example includes a Washington DBR section constructed in 1995 that has still not developed any significant faulting. DBR as part of CPR is critical to successful future non-doweled pavement life.

California. DBR projects have performed well in California, with typical service life between 10 and 15 years. DBR joints have been tested using the Falling Weight Deflectometer for LTE, which is the ultimate DBR performance criterion (typical DBR joints have an LTE > 80 percent). Some projects may require undersealing first to provide sufficient support so that DBR can do its job to increase LTE.

Minnesota. DBR is applied on both non-doweled JPCP and at transverse working cracks of JRCP. The biggest problem is deterioration of the proprietary slot material, perhaps due to too much water in the mix. DBR should last 25 years if the surrounding PCC is sound and the repair material remains durable. A Minnesota contractor estimates 20+ years if the DBR is properly constructed and applied.

Missouri. DBR has been applied mostly at working transverse cracks of JRCP. The types of deterioration include minor spalling, joint faulting, and cracking. Performance has been very good to date, with the oldest projects 10 years old under heavy I-70 truck traffic and showing good performance (no failures). A Missouri contractor says that all projects are lasting >10 years. He has observed >20 years on a few projects in other States.

Utah. Types of DBR deterioration include minor spalling, joint faulting, and cracking. Performance has been excellent to date for 11 DBR projects that were constructed over the past 15 years. The oldest project is 15 years old and is expected to last at least through 20 years.

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Funding—This study was sponsored by the U.S. Federal Highway Administration.

TRT Terms/Keywords— Concrete pavements, Dowel bar retrofit, Pavement maintenance

Availability—This Tech Brief is available from the MoDOT Innovation Library at https://library.modot.mo.gov/RDT/reports/TR201618/